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ON THE EFFECT OF SELF-INTERRUPTION OF GENERATION IN A RUBY OPTICAL QUANTUM GENERATOR

(Presented by Academician I. V. Obreimov, May 4, 1966)

We have discovered the effect of premature interruption of generation in a ruby optical quantum generator, clearly manifested when certain transparent substances are placed in the optical resonator. The study of the influence of the optical properties of media located in the resonator on the laser operating regime is essential for generating stimulated combination and Mandelstam–Brillouin scattering, for internal modulation, and is important for understanding the physics of generation in real solid-state optical quantum generators. In connection with this, a comparative study was carried out of free generation of an optical quantum generator on a ruby crystal and of generation with additional media introduced into the resonator.

Plane-parallel cuvettes (up to 1′) with liquids (benzene, water, glycerin, liquid nitrogen) and solid transparent substances (glasses and plastics of various kinds) were introduced into an optical resonator 700 mm long. The thickness of the liquid layers was $50 \div 300$ mm, and that of the solid bodies $30 \div 120$ mm. Ruby crystals of diameter 8; 10; 12 and 13 mm and length 120 mm were used, with polished and matted lateral surfaces and with an optical-axis orientation of 90°. The output energy, mode composition, and temporal characteristics of the radiation were measured.

The main results of the investigations are as follows.

1. Under conditions of equality of pump energies and initial thresholds, when the optical quantum generator operates with media additionally introduced into the resonator (glycerin, liquid nitrogen, plastics), a substantial decrease in the duration of generation* occurs (Fig. 1b) in comparison with the regime of free generation (Fig. 1a).

Fig. 1

Figure 1: Fig. 1

2. In contrast to the ordinarily observed monotonic increase in the generation duration Δt_{gen} with increasing above-threshold pumping W/W_{th}, the dependence $\Delta t_{\text{gen}}(W/W_{\text{th}})$ in the case of generation with additionally introduced media has an anomalous character (Fig. 2, 1). In the limit, as the pumping is increased, the duration of generation is shortened down to a single spike.

3. When the initial generation threshold is raised by increasing the mirror transmission, their inclination, beam diaphragming, etc., the maximum of the curve $\Delta t_{\text{gen}}(W/W_{\text{th}})$ shifts toward smaller above-threshold pumpings.

At sufficiently high values of the initial resonator losses ($\sim$ 70%), the effect of shortening the generation duration with increasing pumping is observed in an optical quantum generator with all the ruby crystals used, **without any introduced media** (Fig. 1c; Fig. 2, curve 2).

4. The decrease in the generation duration with increasing pumping is accompanied by saturation of the output radiation energy (Fig. 2, curves 3 and 4).

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* Introducing water, benzene, and glasses into the resonator at the same pump energies does not yet cause a noticeable shortening of the generation duration.

5. A reduction in the duration of generation is accompanied, as a rule, by an ordering of the temporal structure of the radiation and a decrease in the scatter of the amplitudes of the spikes in a train.

Analysis of the experimental data obtained leads to the supposition that the observed anomalies are associated with different characteristics of the variation of gain and losses during pumping and generation for each of the cases investigated.

Fig. 1. Oscillograms of the radiation of a ruby optical quantum generator for three values of the above-threshold pumping: I–$W/W_{\text{thr}} = 1.1$; II–2; III–3. a–free generation; the optical resonator was formed by two mirrors with reflection coefficients $R_1 = R_2 = 98\%$; b–inside the resonator a layer of glycerin, 300 mm, was introduced; c–the resonator was formed by a mirror ($R = 98\%$) and the end face of the ruby crystal. In case a the signal amplitude is attenuated by a factor of 3.

From comparison of the oscillograms of the induced radiation and of the light-pumping pulses, carried out by the method developed in work ([1])*, it follows directly that, in the case of an anomalous reduction of the duration of radiation during operation of the optical quantum generator, an increase in the effective

Fig. 2

Figure 2: Fig. 2

generation threshold occurs. This causes a premature termination of generation, which we have called self-quenching**. The absence of generation after self-quenching for, at a minimum, the duration of the flash of the pulsed lamp indicates a sufficiently long relaxation time of the losses that arise ($\sim 10^{-4}$ sec). One of the reasons for the increase in the effective threshold during generation may be a detuning of the optical resonator as a result of the excitation of elastic oscillations ([4]), due to transfer of part of the energy of the light field to the medium.

Fig. 2. Dependence of the duration of generation Δt_{gen} (curves 1, 2) and of the output energy E_{out} (curves 3, 4) on the above-threshold pumping W/W_{thr}. Curves 1 and 3 are for a resonator ($R_1 = R_2 = 98\%$) with an introduced 150-mm layer of glycerin; 2 and 4 are for a resonator formed by a mirror ($R = 98\%$) and the end face of the crystal, without additionally introduced media.

* The construction of the dependences of the radiation intensity of a ruby optical quantum generator on the pumping intensity was carried out taking into account the lifetime of the excited states, under the assumption of a quasi-stationary approximation of the multimode regime.

** Clarification of the effect of the varying losses on the duration and mode composition of the generation of an individual spike ([2,3]) is the subject of further investigations.

it is possible that, when ruby radiation passes through the liquid, phenomena of self-focusing of the beam arise ([5]), accompanied by effects of stimulated emission.

We note that, during operation of a ruby O.Q.G. with a nonlinear filter of KS-18, when several spikes are generated, an increase is observed in the interval between the last spikes, which is not connected with a change in the shape of the pump pulse. This may be determined by a change in the optical properties of the KS-18 glass during the generation process, analogous to that observed in self-quenching.

Usually, ordering of the spike structure is associated with mode selection. However, a study of the spectrum of longitudinal modes by means of a Fabry–Perot interferometer did not reveal any substantial difference in the modal composition for the two cases of O.Q.G. operation. It should be assumed that the observed ordering of the generation is determined by selection of transverse modes.

The reduction, obtained in works ([6,7]), of the generation duration and saturation of the output radiation energy of an O.Q.G. at the temperature of liquid nitrogen, as well as the ordering of the spike regime of ruby generation placed in

a cuvette with glycerin, is apparently determined by the phenomenon discussed in the present communication.

In conclusion, we point out the possibility of using the observed effect for controlled dosing of the output radiation energy of an O.Q.G.

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Note: Figure translations are in progress. See original paper for figures.